APPLICATION OF INTERFERENCE AND HOLOGRAPHIC METHODS TO THE STUDY OF COMBUSTION PROCESSES IN COAXIAL BURNERS

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The possibility of studying combustion processes between tube endfaces of coaxial burners by interference and holographic methods is discussed. The advantages of holographic over interference methods are demonstrated.

Flame ignition of a gas in a coaxial burner, with gas and air supplied in alternate layers, can, under certain conditions, give rise to oscillating combustion modes. The study of such processes is interesting both from a theoretical and a practical standpoint.

The type of burner described in [1, 2] was used in our experiments. It consisted of two concentric tubes with end faces displaced a distance h from one another (Fig. 1a). The fuel gas is supplied along the interior tube and air is delivered through the radial clearance between the walls of the interior and exterior tubes. It is known [1, 2] that the cause of flame pulsations is the periodic accumulation and combustion of the fuel mixture in the space between the tube end faces, which determines flame characteristics such as the pulsation amplitude and frequency. Investigation of changes in the processes occurring between the tube end faces produced by various physical techniques capable of influencing the combustion, e.g., the application of external electric fields [3], is of considerable interest. Valuable information about these processes can be obtained by the application of optical methods, such as shadow and interference techniques, and also holographic interferometry methods, which we also classify as optical.

To get an interference pattern for the process of combustion between tube end faces a portion of the exterior tube was replaced by plane-parallel optical glasses (Fig. 1b). A total shift polarizing setup, based on instrument IAB-545 (Fig. 3a) [4] was used. The total shift principle was selected so as to simplify the interpretation of interferograms. The use of high-speed filming (SKS-1M, 2100 frames/sec) produced interference films which allowed investigation of the process of accumulation and combustion of the fuel mixture and observation of heat flow variations in the presence and absence of an external electric field. One frame from the high-speed film is shown in Fig. 3a.

However, the method described has certain disadvantages. First, the presence of the glasses interferes with the cylindricity of the exterior tube (its cross section becomes rectangular). Because of this the process of fuel-mixture combustion and accumulation between the tube end faces differs slightly from that which would occur with a cylindrical exterior tube. Second, instead of observing the whole area between the tube end faces, only that portion of it which is replaced by optical glasses can be observed. These shortcomings can be eliminated by the use of holographic methods.

It is known that certain methods of holographic interferometry provide means for the investigation of phase dynamic problems which it is impossible to study with classical interferometry methods [5, 6]. It was this fact that provided the basis for the present work. The methods used to obtain interferograms of heat flows in the coaxial burner were that of double exposure with a disperser placed in front of the objective to produce separate photographs, and that of holographic interferometry in real time for visual observation with the aid of a gas laser. The optical scheme of the holographic interferometer is shown in Fig. 3b.

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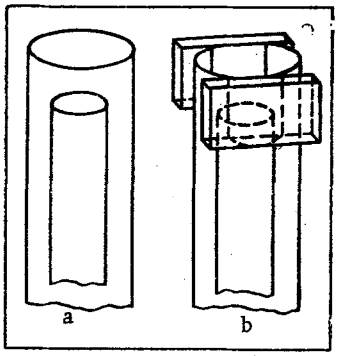

Fig. 1

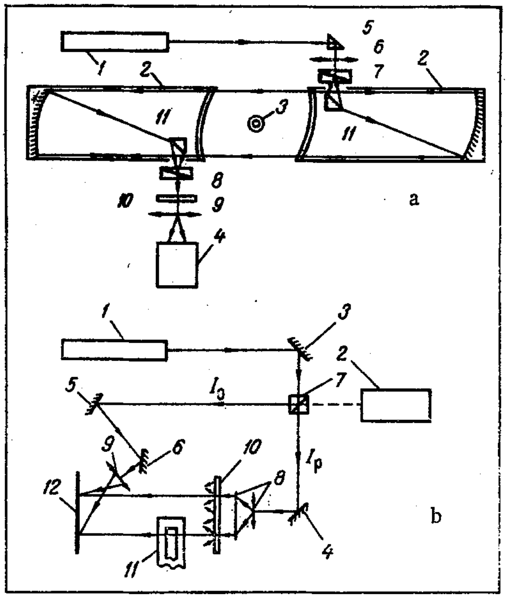

Fig. 2

Fig. 1. External view of the coaxial burner: a) without optical glasses; b) with optical glasses.

Fig. 2. Optical schemes of polarization and holographic interferometers; a) polarization interferometer based on IAB-451 (1 — gas laser; 2 — collimating and viewing sections of instrument IAB-451; 3 — coaxial burner; 4 — high-speed film camera SKS-16-1M; 5 — turning prism; 6, 10 — lenses; 7, 8 — Wollaston prisms; 9 — analyzer; 11 — mirrors); b) holographic interferometer with diffuse disperser (1 — gas laser LG-38; 2 — ruby pulse laser; 3,4,5,6 — mirrors; 7 — light divider; 8,9 — lenses forming the working and base beams; 10 — diffuse disperser; 11 — coaxial burner; 12 — hologram).

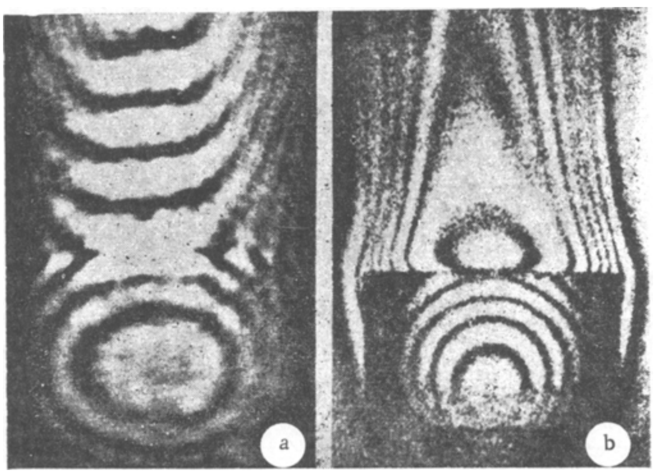

Fig. 3. Interferograms of the combustion process between tube end faces: a) taken with a polarization interferometer; b) taken by holographic methods.

The coherent light sources used were a supermode gas laser of type LG-38 and a ruby pulse laser, generating at its natural frequency. A diaphragm was installed in the resonator of the latter to select transverse modes. A light divider was used to divide the laser emission into two beams: a base beam I_0 and a working beam I_W with intensities related by $I_W = 2I_0$. The working beam passes through the plane diffuse disperser 10 into the coaxial burner 11. The disperser used was a 2-mm-thick glass plate with a matte surface on one side.

The hologram was registered on an experimental, extra-high resolution film for holography, type FPGV-2, using the method of double exposure with an exposure time determined by the laser pulse duration $\tau = 0.8 \cdot 10^{-8}$ sec. The holography angle was $\alpha = 30°$. The interferograms recorded on the film (Fig. 3b) were obtained in the direction of the working beam axis.

The disturbance of the coaxial arrangement of the space between the burner tube end faces caused by replacing part of the exterior tube by plane-parallel optical glasses produces changes in the shape of the flame front and in the flow dynamics of the fuel mixture and combustion products. It is these changes which produce the differences between photographs of the interference patterns of the processes in the burner taken by interference and by holographic methods. Figures 3a and b show photographs of the accumulation of fuel mixture between the burner end faces and of the flame tongue above the exterior tube.

The interferograms were interpreted by the well-known method of Schardin [7], taking into account the relative positions of the disperser, the coaxial burner, and the photographic film section from which the interferogram was obtained. In conclusion, an additional advantage of the holographic method should be mentioned. In calculating the temperature fields by Schardin's method, it is not necessary to introduce corrections for the nonhomogeneity of the optical glasses and for the fact that they are not precisely parallel.

NOTATION

h, distance between end faces of exterior and interior tubes of coaxial burner; I_0, base beam intensity; I_w, working beam intensity; τ, laser pulse duration; α, angle between working and base beams.

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